HIGH-STRENGTH ALUMINUM ALLOYS

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The modern methods of alloying made possible to increase hardness of Al alloys to 2200 MPa, yield stress to 700 MPa and ultimate tensile stress to 800 MPa. High strength characteristics of these alloys are combined with plasticity to fracture 5-15 % that is enough for the practical use. Taking into account low density of aluminum alloys (~ 2.7 g/cm^3), it is seen that these alloys have very high specific strength - more than for steels.

The alloys of Al-Zn-Mg-Cu system have the higher strength characteristics among wrought Al alloys. These alloys are the basic structural materials for aerospace engineering. Their strengthening is due to a very fine precipitation of η'-phase.

Additional alloying of these alloys by Sc and Zr is very effective. A diverse effect of alloying with Sc and Zr is stipulated by specific properties of the $Al_3(Sc_{1-x}Zr_x)$ intermetallic phase that forms fine coherent precipitates in the Al matrix. These coherent particles are very stable upon heating due to low solubility and diffusivity of Sc and Zr in the Al matrix and low interface energy. Combined alloying with Sc and Zr in the amount as low as 0.2 % refines microstructure of casting and welding, improves workability and deformability of castings, leads to formation of a very uniform and fine cellular dislocation structure in wrought products, and impedes recrystallization during heat treatment due to the obstacle action of the coherent particles.

High strength (up to 820 MPa) was achieved in Al-Zn-Mg-Cu alloys additionally alloyed by Sc and Zr. The recrystallization temperature of these alloys is very high, and after T6 treatment alloys have non- recrystallized structure. This non-recrystallized structure is more ductile, because brittle fracture along grain boundaries is not developed. An addition of Sc in combination with Zr, Mn and Cr increases the size of η'-particles, leading to an increase in ductility. A decrease in strength accompanying this growth is compensated and even exceeded by contribution of small $Al_3(Sc_{1-x}Zr_x)$ coherent particles to hardening.

The important beneficial effect of alloying with Sc in combination with Zr is the possibility of increasing the concentration of Zn without loss in ductility.

It was shown that additions of Sc increase the resistance of Al and its high-strength alloys against general and pitting corrosion in the sea water.

Al-Zn-Mg-Cu alloys containing Sc may be used even at cryogenic temperatures where these alloys have good combination of strength and ductility.

The best Al wrought alloys for elevated temperature application were obtained using dispersion strengthening by quasicrystalline particles 15-50 nm in diameter with volume fraction 50-70 % in Al matrix.

We have used in our experiments quasicrystalline phase $Al_{84.2}Fe_7Cr_{6.3}Ti_{2.5}$. For the alloy of Al-Fe-Cr-Ti system obtained by rapid solidification technique with the following compacting of powders, the strength at 300 ^oC was more than 300 MPa. The structure and mechanical properties of these alloys are stable up to 400 ^oC.

The high-strength cast alloys with good castability and increased mechanical properties were elaborated on the base of eutectic composition Al-13 vol.%Mg_2Si with additional alloying by transition and rare-earth metals.

The development of this direction is the elaboration of cast eutectic alloys in the system Al-Ti-Cr, containing $L1_2$ phase. These alloys have higher melting point (1275 ^oC) high Young's modulus (up to 190 GPa), essential ductility in compression tests and high hardness and strength up to 800 ^oC.